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Turbulent Transport Regulation by Zonal Fows in Helical Systems with Radial Electric Fields[1]

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Zonal flows are now well known to play a critical role in regulation of turbulent transport in plasmas. Therefore, for the purpose of improving plasma confinement, it is very important to investigate effects of magnetic configuration on zonal flows generated by turbulence [1-3]. Furthermore, in helical systems such as heliotrons and stellarators, the neoclassically-driven ExB rotaion, which is distinguished from the microscopic sheared ExB zonal flows, is expected to strongly influence not only neoclassical transport but also turbulent transport through enhancing zonal-flow generation [4,5]. In this work, gyrokinetic theory and simulation results are presented to show how the helical geometry and the ExB rotaion affect zonal flows and ion temperature gradient (ITG) turbulent transport. Larger zonal-flow generation and turbulent transport reduction are found by the gyrokinetic ITG turbulence simulation for the neoclassically optimized helical configuration, in which radial drift velocities of ripple-trapped particles decrease [6]. Further zonal-flow enhancement by the ExB rotaion can occur effectively with neoclassical optimization due to the reduction of radial displacements of ripple-trapped particles. These findings are consistent with the confinement improvement observed in the inward-shifted configuration of the Large Helical Device. Also, it is expected that this ExB effect on zonal flows causes the ion mass dependence of the ITG turbulent transport to differ from the conventional gyro-Bohm scaling in a favorable way because the zonal-flow generation increases with increasing the ratio of the ExB velocity to the ion thermal velocity. [1] H. Sugama and T.-H.Watanabe, Phys. Rev. Lett. 94, 115001 (2005). [2] H. Sugama and T.-H. Watanabe, Phys. Plasmas 13, 012501 (2006). [3] T.-H. Watanabe, H. Sugama, and S. Ferrando-Margalet, Nucl. Fusion 47, 1383 (2007). [4] H. Sugama, T.-H. Watanabe, and S. Ferrando-Margalet, Joint Conference of 17th International Toki Conference on Physics of Flows and Turbulence in Plasmas and 16th International Stellarator/Heliotron Workshop 2007 (Toki, Japan, 2007), PI-08. [5] H. E. Mynick and A. H. Boozer, Phys. Plasmas 14, 072507 (2007). [6] T.-H. Watanabe, H. Sugama, and S. Ferrando-Margalet, Phys. Rev. Lett. 100, 195002 (2008).

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